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(54) Electrochemical cell apparatus having combusted exhaust gas heat exchange and valving to control the reformable feed fuel composition.

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(56) References cited:
EP-A- 0 076 019
EP-A- 0 328 812
US-A- 3 718 506
US-A- 4 729 931
BBC NACHRICHTEN. vol. 54, no. 1/2, January 1972, MANNHEIM DE pages 4 - 12; W.FISCHER: 'Hochtemperatur-Brennstofzellen-Aggregat zum Umsatz von Kohlenwasserstoffen"
PATENT ABSTRACTS OF JAPAN vol. 12, no. 493 (E-697)(3340) December 22, 1988 & JP-A-63 207 054 (FUJIKURA LTD) August 26, 1988
PATENT ABSTRACTS OF JAPAN vol. 12, no. 174 (E-612)(3021) May 24, 1988 & JP-A-62 283 570 (MITSUBISHI HEAVY IND LTD) December 9, 1987

(56) References cited:
PROCEEDINGS ELECTROCHEMICAL SOCIETY (SYMPOSIUM ON FUEL CELLS, 6-7 November 1989 SAN FRANSISCO, CALIFORNIA) vol, 89, no14, 1989, PENNINGTON (US) pages 106-117; L.A SHOKLING AND ALL: "Development of a commercially practical natural gas fueled SOFC generator " * page 110, column 1- column 2; figure 7 *

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Description

This invention relates to an electrochemical apparatus containing a plurality of electrochemical cells, each having an exterior fuel electrode, which can be contacted by a mixture of fresh feed fuel and recirculated spent fuel, which mixture contains water vapor and can pass through a reforming material prior to contacting the fuel electrodes, where recirculated, combusted exhaust gas surrounds and heats the reforming material, and fresh feed fuel and recirculated spent fuel can be mixed precisely by valving controls prior to contact with the cells.

High temperature, solid oxide electrolyte fuel cell generator apparatus and fuel cell configurations are well known. There, feed fuel, either H_2+CO, or previously reformed natural gas, is fed into the apparatus at one end and flows parallel to exterior fuel electrode surfaces of elongated fuel cells. Spent fuel is combusted with spent oxidant in a separate chamber and then exits the apparatus.

Other high temperature fuel cell generator apparatus designs are known, where spent fuel is recirculated and aspirated into fresh, preheated feed fuel, in the center of the apparatus, at apparent temperatures of approximately 600°C to 800°C, which mixture is fed through the fuel cells, as taught in U.S. Patent Specification No. 3,718,506 (Fischer et al.). There, spent fuel exiting the fuel cells, is mixed with fresh feed fuel, such as propane, at a jet-pump nozzle, for flow inside of series connected fuel cells. This combination of spent fuel with fresh fuel prevents soot formation within the cells. Additional spent fuel mixes with spent air and flows around and through a catalytic afterburner structure surrounding the fuel cells for complete combustion, which heats the fuel cells, allowing efficient operation at approximately 800°C. In U.S. Patent Specification No, 4,729,931 (Grimble), spent fuel and combusted fuel are mixed, and then drawn into fresh feed fuel at an ejector nozzle, in an interior chamber of the generator apparatus. The entire mixture then passes through a reforming material, located in the same chamber as the ejector, to form a reformed gas which is fed to contact fuel cells within the apparatus.

Another generator design to prevent chilling of the fuel cells is taught in U.S. Patent Specification No. 4,808,491 (Reichner) where a combusted exhaust of spent fuel and spent oxidant provides corner heating in the generator apparatus. There, fresh feed fuel is fed into a manifold at the bottom of the apparatus, the bottom of which manifold may contain reforming catalyst and may be heated by the combusted exhaust. The feed fuel then flows parallel to the exterior fuel electrode surfaces of the elongated fuel cells. The fresh feed fuel is not mixed with any spent gases.

Natural gas (methane plus ethane, propane, butane and nitrogen) is a likely fuel for many of these fuel cell apparatus. This natural gas must be reformed, that is, converted to carbon monoxide and hydrogen, through the use of a catalyst and excess water vapor, prior to its utilization in the fuel cell. The reforming reaction is endothermic, requiring a supply of heat, and is best performed at temperatures close to 900°C. The heat required for reforming is a significant fraction of the excess heat that results from fuel cell operation.

The use of recirculated spent fuel to provide water vapor and CO_2 for fresh feed fuel, by means of an ejector powered by the inlet fresh fuel pressure, has the potential to result in several problems. In many instances, the composition of the fresh feed fuel may vary, requiring control of the amount passing through the ejector, and also control of the amount of water vapor laden spent fuel. Also, too great a draw of spent fuel at the ejector, will reduce the Nernst potential in a significant portion of the generating chamber of the apparatus and will result in lower operating voltage or poorer utilization of fuel than desired.

What is needed is an apparatus which allows more efficient heating of internal reforming material, and which controls spent fuel inclusion into the fresh feed fuel. It is one of the main objects of this invention to provide such an apparatus.

BBC Nachricten, Vol. 54, No. 1/2, January 1972, pp. 4-12, 'High Temperature Fuel Cell Battery for The Conversion of Hydrocarbons' (Fischer et al) describes an axially elongated fuel cell apparatus, where depleted fuel, consisting of H_2O vapor and CO_2, from the battery chamber is directly mixed, at a mixing nozzle, with fresh fuel, and the mixture passed through axially elongated tubes containing catalyst for reforming the mixture, which catalyst containing tubes are spaced apart from the depleted fuel exit tube. Oxidant is passed through feed tubes into the interior of the fuel cells where it is depleted before passing into the heat exchange part of the apparatus and then exiting. The battery chamber is located at the end of the apparatus away from the heat exchange chamber and the catalyst reforming tubes.

Proceedings Electrochemical Society (Symposium on Fuel Cells, 6-7 November 1989), Vol. 89, No. 14, pp. 106-117, 'Developments of a Commercially Practical Natural Gas Fueled SOFC Generator' (Shockling et al) describes external and internal reformers for fuel cell generators, where water vapor is essential to the reformation reaction. In an internal reformer embodiment, depleted fuel containing water vapor is recirculated to the reformer along with 56% of the natural gas, obviating the need for a separate steam generator. The remaining 44% of the depleted fuel is reacted with oxidant and exits the system. The heat content of the recirculated gas covers the heat requirement of reformation. The mixer and ejector are internal to the apparatus.

Accordingly, the invention resides in an axially elongated electrochemical apparatus having: fresh gaseous feed fuel inlet; gaseous feed oxidant inlet; gaseous spent fuel recirculation channel; separate, hot combusted gas exit channel; a combustion chamber; a generator chamber located between the combustion chamber and a reforming chamber and containing a plurality of axially elongated electrochemical cells, each cell having an exterior fuel electrode and an interior air electrode; and a reforming chamber containing a reforming material; characterized in that the spent fuel recirculation channel passes from the generator chamber to combine with the fresh feed fuel inlet at a circulation and mixing apparatus, a reformable fuel mixture channel connects the circulation and mixing apparatus and a separate reforming chamber, the separate reforming chamber is connected to the generator chamber, a separate combustion chamber is provided for combustion of spent fuel and spent oxidant to provide hot combusted gas, and the separate hot combusted gas exit channel is connected to the combustion chamber and a portion of the hot combusted exhaust gas exit channel surrounds the reforming chamber allowing hot gas flow transverse to the central axis of the reforming chamber and the apparatus, and the fresh feed fuel inlet has a by-pass channel into the gaseous spent fuel recirculation channel said by-pass channel having valving to control fresh feed fuel flow to the gaseous spent fuel recirculation channel. fresh feed fuel flow to the gaseous spent fuel recirculation channel.

The term "fuel electrode" as used herein means that electrode in contact with fuel, the term "air electrode" as used herein means that electrode in contact with air or oxygen, and the term "spent" fuel oxidant, or air as used herein means reacted, depleted fuel or reacted, depleted oxidant or air containing about 5% to 18% oxygen. The term "spent" fuel does not include the mixture of spent fuel combusted with spent oxidant or air, which mixture is herein defined as "combusted exhaust gas". The term "surrounds" as used herein means at least passing around and in contact with a major portion of the side of a vessel.

The use of combusted exhaust gas having a temperature of approximately 1,000°C as the prime source of thermal energy for the endothermic reformation reaction optimizes recuperative heat exchange in the apparatus. The use of a valving control and by-pass of fresh feed fuel gas flow allows regulation of the amount of spent fuel aspirated at the circulation and mixing device, and thus water vapor and carbon dioxide in the spent fuel that is recirculated. The recirculation fraction will be determined by the desired oxygen-to-carbon ratio in the mixed fuel stream prior to entering the reformer. The channels which carry the combusted exhaust gas and the reformable fuel mixture may be concentric with the reforming chamber, with heat conduction fins providing a recuperative heat exchange between the two gas streams.

In order that the invention can be more clearly understood, conventional embodiments thereof will now be described, by way of example, with reference to the accompanying drawing, which is a side view in section of one embodiment of an electrochemical cell apparatus according to this invention, showing recirculation of combusted exhaust gas, mixture of spent fuel with incoming fresh feed fuel, and a by-pass channel to route fresh feed fuel directly into the gaseous spent fuel recirculation channel.

Referring now to Figure 1, an electrochemical cell apparatus or generator 10 is shown containing two cell bundles 12 and 14, each bundle containing a plurality of parallel, axially elongated electrochemical cells 16, such as solid oxide fuel cells. The cells are located in generator compartment or section 22. Each cell has an exterior fuel electrode 18 covering its axially elongated surface, shown dotted for the sake of clarity, an interior air electrode, and a solid oxide electrolyte between the electrodes (air electrode and electrolyte not shown). The air electrode is generally a doped ceramic of the perovskite family, for example, doped $LaMnO_3$, the electrolyte is generally yttria stabilized zirconia, and the fuel electrode is generally a zirconia-nickel cermet material. A calcia stabilized zirconia support for the air electrode can also be used.

The electrochemical cell apparatus 10 will operate with an interior temperature in the range of about 600°C to 1,200°C. An outer housing 20 surrounds the entire apparatus. An inner housing, not shown, surrounds a plurality of chambers, including the generator chamber 22 and a combustion chamber 24 and is preferably comprised of a high temperature resistant metal or alloy. Thermal insulation 26, such as low density alumina insulation board is contained within the outer housing as shown. Penetrating the housing 20 and insulation 26 is fresh gaseous feed fuel inlet 28, the fresh feed fuel shown as F, and a gaseous oxidant, such as air or oxygen, feed inlet 30, as well as ports for electrical leads and the like, not shown. The generator chamber 22 extends between wall 32 and a porous barrier 34. The porous barrier 34 need not be a sealed structure. The porous barrier 34, in particular, is designed to allow spent fuel gas flow, indicated by arrows 36, between the generator chamber 22, operating at a pressure slightly above atmospheric, and the combustion chamber 24, operating at a slightly lower (but still above atmospheric) pressure.

High temperature, elongated, solid oxide electrolyte cells 16 extend between the combustion chamber 24 and the wall 32. The cells have open ends 44 in the combustion chamber 24, and closed ends in the generator chamber 22 near wall 32. Each individual cell generates approximately one volt on open circuit, and a plurality are electrically interconnected through conducting felts 40, usually nickel fiber metal, preferably in a series-parallel rectangular array.

EXAMPLE

By way of example, during operation, a gaseous feed oxidant, such as air, is fed through oxidant feed inlet 30, and enters the oxidant feed conduits 42 at a temperature of approximately 500°C to 700°C, and a pressure above atmospheric, being optionally heated prior to entering the housing by conventional means, such as a heat exchanger coupled with a blower. The oxidant, within the conduits, is passed through the combustion chamber 24, where it is further heated to a temperature of approximately 800°C to 900°C by combusted exhaust gas. The oxidant then flows through the length of the oxidant circuit, through the conduits 42 which extend down the inside length of the fuel cells, being further heated to approximately 1,000°C, by virtue of absorbing most of the heat generated during the electrochemical reaction. A smaller fraction of the heat is absorbed by the fuel.

The oxidant is discharged into the closed end bottom of the fuel cells 16. The oxidant within the fuel cells reverses direction, and electrochemically reacts at the inner air electrode along the inside active length of the cells, depleting somewhat in oxygen content as it approaches the open ends 44 of the cells. The depleted oxidant is then discharged into the combustion chamber 24 through the open cell ends 44, and is shown as spent oxidant streams 35. This spent oxidant combusts with depleted fuel, where part of the total depleted fuel passes through porous barrier 34 as shown by arrows 36, to form combusted exhaust gas 47, which exits the apparatus through separate combusted exhaust gas exit channels 45, finally exiting as exhaust gas E. The channels 45 can be made of a high temperature resistant metal or alloy.

In this invention, a gaseous fuel that has not yet been reformed, such as a gaseous hydrocarbon, including hydrocarbons such as methane (CH_4), ethane (C_2H_6), propane (C_3H_8), and the like, vaporized petroleum fractions such as naphtha, and alcohols, such as ethyl alcohol (C_2H_5OH), and the like, and natural gas, that is, a mixture of 85% methane, and 10% ethane with a balance of propane, butane and nitrogen, can be used. These reformable fuel mediums F are fed into the generator through fresh feed fuel inlet 28.

In this invention, a major portion of the hot gaseous spent fuel formed along the axial length of the cells 16 passes to at least one spent fuel recirculation channel 46, which can be made of a high temperature resistant metal or alloy. Another portion of the hot spent fuel passes into combustion chamber 24, shown as arrows 36 as previously described, to combust with spent air, shown as arrows 35, and preheat the fresh oxidant feed. The spent fuel recirculation channel 46 passes from the generator chamber 22 to feed into and combine with the fresh feed fuel inlet at a circulation and mixing apparatus 50, which can be of any type known in the art, for example, an ejector, jet pump, aspirator, or the like, which is positioned in a cooler region of the insulation, as shown. This allows recirculation of a portion of the spent fuel fed into channel 46 to mix with the fresh feed fuel at mixer 50, to provide a reformable fuel mixture 51 which passes through reformable fuel mixture channel 64 on route to reforming chamber 54.

The reformable fuel mixture 51 will contain at least water vapor (steam) and usually also H_2, CO, and CO_2, all contributed by the spent fuel that enters circulation-mixing apparatus 50. Preferably, the volume ratio of spent fuel to fresh feed fuel will be adjusted in the mixer 50 so that approximately 2 volumes to 5 volumes of water vapor and CO_2 are added to each volume of fresh feed fuel, when the fuel is natural gas. The presence of water vapor plus a reforming catalyst, most commonly Ni allows conversion of gaseous hydrocarbons to $CO+H_2$, by the reaction:

$$CH_4 + H_2O_{(g)} \xrightarrow[\text{(nickel catalyst)}]{\text{endothermic reaction}} 3H_2 + CO$$

The reformable fuel mixture 51 then passes through a reforming chamber 54, shown half in section, containing reforming material 56, such as nickel, or other well known useful reforming material for fuel gas. For example, a nickel salt, such as nickel nitrate, may be impregnated into an alumina based material and then heated to form the nickel oxide and reduced to nickel. The design shown in the Drawing for the reforming chamber 54 is a circular vessel surrounded by the annular portion 45' of the combusted exhaust gas exit channel, allowing heat transfer from channel section 45' to chamber 54. As shown, the channel section 45' almost completely surrounds the sides of the reforming chamber 54 allowing axial combustion gas flow or flow transversely around the central axis of the chamber 54 as shown by arrow 60. The central axis of the reforming chamber would be parallel to arrow 51 in the drawing. The channel section 45' could also completely surround the vessel 54.

The reformed fuel mixture, shown by arrows 58, after passing through the reforming material 56, passes through a series of ports which connect the reforming chamber to the generator chamber, and into the generator

chamber 22 portion of the apparatus. The heat transfer surface area of channel 45′ passing around the periphery of the reforming chamber 54 is large, so ample opportunity is provided for heating the reforming material 56.

Hot combusted exhaust gas from channel 45 reaches channel 45′ at a temperature of approximately 850°C. Thus, channel 45′, in contact with the reforming chamber 54, allows recuperative heat transfer between that channel and chamber. An exhaust gas bypass channel (not shown) may be used to adjust the flow of exhaust gas through channel 45′, so that the fuel temperature may be controlled at entrance to the generator chamber 22. This may produce a more uniform cell temperature within the generating chamber 22. With regard to the reformer 54, some internal reforming of the reformable fuel mixture can be utilized. Catalytic reforming material can be distributed within the generator chamber on or adjacent to cells or elsewhere in the generator chamber. Nickel fiber felts 40, or the nickel cermet surface 18 of the fuel cells, can be utilized to keep the amount of reforming material 56 relatively small.

Additionally, fresh fuel feed inlet 20 has one or more by-pass channels 62 so that fresh fuel feed can bypass the aspirating portion of apparatus 50, and flow directly into the gaseous spent fuel exit channel 46, as shown. Each by-pass channel 62 has appropriate valving means or other metering means, as shown, to control the flow of fresh feed fuel into the gaseous spent fuel recirculation channel. This allows control of the quantity of spent fuel gas recirculated through channel 46 into the mixing apparatus 50. Apparatus 50 will usually contain a nozzle from which fresh feed fuel will exit at a high velocity, thereby entraining and circulating the spent fuel gas from channel 46. The amount of by-pass flow through each channel 62 can be varied by the valve V, allowing a reduction in the amount of spent fuel gas, and thus water vapor, entrained within apparatus 50, in order to assure that an appropriate H_2O:gaseous hydrocarbon, or O:C ratio is achieved under various operating conditions. A preferred volume ratio of H_2O:fresh feed fuel is from approximately (1.2:1) to (3:1), for natural gas fuel.

Claims

1. An axially elongated electrochemical apparatus (10) having: fresh gaseous feed fuel inlet; gaseous feed oxidant inlet; gaseous spent fuel recirculation channel (46); separate, hot combusted gas exit channel (45); a combustion chamber (24); a generator chamber (22) located between the combustion chamber and a reforming chamber (54) and containing a plurality of axially elongated electrochemical cells, each cell having an exterior fuel electrode and an interior air electrode; and a reforming chamber (54) containing a reforming material; characterized in that the spent fuel recirculation channel (46) passes from the generator chamber to combine with the fresh feed fuel inlet at a circulation and mixing apparatus (50), a reformable fuel mixture channel (64) connects the circulation and mixing apparatus (50) and a separate reforming chamber (54), the separate reforming chamber (54) is connected to the generator chamber (22), a separate combustion chamber (24) is provided for combustion of spent fuel and spent oxidant to provide hot combusted gas, and the separate hot combusted gas exit channel (45) is connected to the combustion chamber (24) and a portion of the hot combusted exhaust gas exit channel (45) surrounds the reforming chamber (54) allowing hot gas flow transverse to the central axis of the reforming chamber and the apparatus, and the fresh feed fuel inlet (28) has a by-pass channel (62) into the gaseous spent fuel recirculation channel (46) said by-pass channel having valving (V) to control fresh feed fuel flow to the gaseous spent fuel recirculation channel (46).

2. The apparatus of claim 1, characterized in that the chambers are within a metal housing lined with insulation.

3. The apparatus of claim 1, characterized in that the electrochemical cells are fuel cells, the air electrode contains doped $LaMnO_3$, the electrolyte is yttria stabilized zirconia and the fuel electrode contains a zirconia-nickel cermet material.

4. The apparatus of claim 1, characterized in that the circulation and mixing apparatus is an ejector mechanism.

5. The apparatus of claim 1, characterized in that catalytic reforming material is also distributed within the generator chamber on or adjacent to the cells or elsewhere within the generator chamber.

6. The apparatus of claim 1, characterized in that heat conduction fins are present at the contact points of

the hot combusted exhaust gas exit channel and the reforming chamber.

7. The apparatus of claim 1, characterized in that it is operating on a gaseous oxidant and a fresh gaseous feed fuel.

Patentansprüche

1. Axial langgestreckte elektrochemische Vorrichtung (10) mit folgendem: einem Einlaß für frischen gasförmigen Zufuhrbrennstoff; einem Einlaß für gasförmiges Oxidationsmittel; einem Rezirkulationskanal (46) für gasförmigen verbrauchten Brennstoff, einem getrennten Ausgangskanal (45) für heißes verbranntes Gas; einer Verbrennungskammer (24); einer Generatorkammer (22), die zwischen der Verbrennungskammer und einer Reformierungskammer (54) angeordnet ist und eine Vielzahl von axial langgestreckten elektrochemischen Zellen enthält, wobei jede Zelle ein äußere Brennstoffelektrode und ein innere Brennstoffelektrode hat; und einer Reformierungskammer (54), die ein Reformierungsmaterial enthält; dadurch gekennzeichnet, daß der Rezirkulationskanal (46) für verbrauchten Brennstoff von der Generatorkammer geht, um sich mit dem Einlaß für frischen Zufuhrbrennstoff bei einer Zirkulations- und Mischungsvorrichtung (50) zu kombinieren, ein reformierbarer Brennstoffmischungskanal (64) die Zirkulations- und Mischungsvorrichtung (50) und eine getrennte Reformierungskammer (54) miteinander verbindet, wobei die getrennte Reformierungskammer (54) an die Generatorkammer (22) angeschlossen ist, eine getrennte Verbrennungskammer (24) geliefert wird, um verbrauchten Brennstoff und verbrauchtes Oxidationsmittel zu verbrennen, um heiße verbrannte Gase zu liefern, und der getrennte Ausgangskanal (45) für heißes verbranntes Gas an die Verbrennungskammer (24) angeschlossen ist, und ein Teil des Ausgangskanals (45) für heißes verbrauchtes Auslaßgas die Reformierungskammer (54) umgibt, was gestattet, daß heißes Gas quer zur mittleren Achse der Reformierungskammer und der Vorrichtung fließt, und der Einlaß (28) für frischen Zufuhrbrennstoff einen Umgehungskanal (62) in den Rezirkulationskanal (46) für gasförmigen verbrauchten Brennstoff hat, wobei der Umgehungskanal ein Ventilsystem (V) hat, um Fluß von frischem Zufuhrbrennstoff zum Rezirkulationskanal (46) für gasförmigen verbrauchten Brennstoff zu steuern.

2. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die Kammern in einem Metallgehäuse liegen, das mit Isolierung verkleidet ist.

3. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die elektrochemischen Zellen Brennstoffzellen sind, die Luftelektrode dotiertes $LaMnO_3$ enthält, der Elektrolyt mit Yttrium stabilisiertes Zirconiumdioxid ist, und die Brennstoffelektrode eine Zirconiumdioxid-Nickelcermetmaterial enthält.

4. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die Zirkulations- und Mischungsvorrichtung ein Auswurfmechanismus ist.

5. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß das katalytische Reformierungsmaterial auch in der Generatorkammer auf oder neben den Zellen oder woanders in der Generatorkammer verteilt ist.

6. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß die wärmeleitenden Rippen an den Kontaktpunkten des Ausgangskanals für das heiße verbrannte Auslaßgas und der Reformierungskammer vorhanden sind.

7. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß sie mit einem gasförmigen Oxidationsmittel und einem frischen gasförmigen Zufuhrbrennstoff arbeitet.

Revendications

1. Appareil électrochimique (10) axialement allongé, qui comprend: une entrée de gaz combustible d'alimentation neuf; une entrée de gaz oxydant d'alimentation; un canal de recirculation (46) de gaz combustible usé; un canal de sortie (45) de gaz brûlé chaud et séparé; une chambre de combustion (24); une chambre de générateur (22) placée entre la chambre de combustion et une chambre de reformage (54) et contenant une pluralité de cellules électrochimiques axialement allongées, chaque cellule comprenant une électrode extérieure à combustible et une électrode intérieure à air,

caractérisé en ce que le canal de recirculation (46) du combustible usé vient de la chambre de générateur pour se combiner avec l'entrée de gaz combustible neuf d'alimentation au niveau d'un appareil (50) de mélange et mise en circulation, un canal (64) de mélange de combustible reformable relie l'appareil (50) de mélange et mise en circulation avec une chambre de reformage séparée (54), la chambre de reformage séparée (54) est reliée à la chambre de générateur (22), une chambre de combustion séparée (24) est fournie pour la combustion du combustible usé et de l'oxydant usé afin de donner un gaz brûlé chaud, et le canal de sortie (45) de gaz brûlé chaud et séparé est relié à la chambre de combustion (24), et une partie du canal de sortie (45) de gaz brûlé chaud et séparé entoure la chambre de reformage (54) en permettant un écoulement de gaz chaud transversalement à l'axe central de la chambre de reformage et de l'appareil, et l'entrée (28) de gaz combustible neuf d'alimentation comporte un canal de dérivation (62) vers le canal de recirculation (46) de gaz combustible usé, ledit canal de dérivation ayant un dispositif de vanne (V) qui règle l'écoulement de combustible neuf d'alimentation vers le canal de recirculation (46) de gaz combustible usé.

2. Appareil selon la revendication 1, caractérisé en ce que les chambres sont à l'intérieur d'une enceinte métallique doublée d'une isolation.

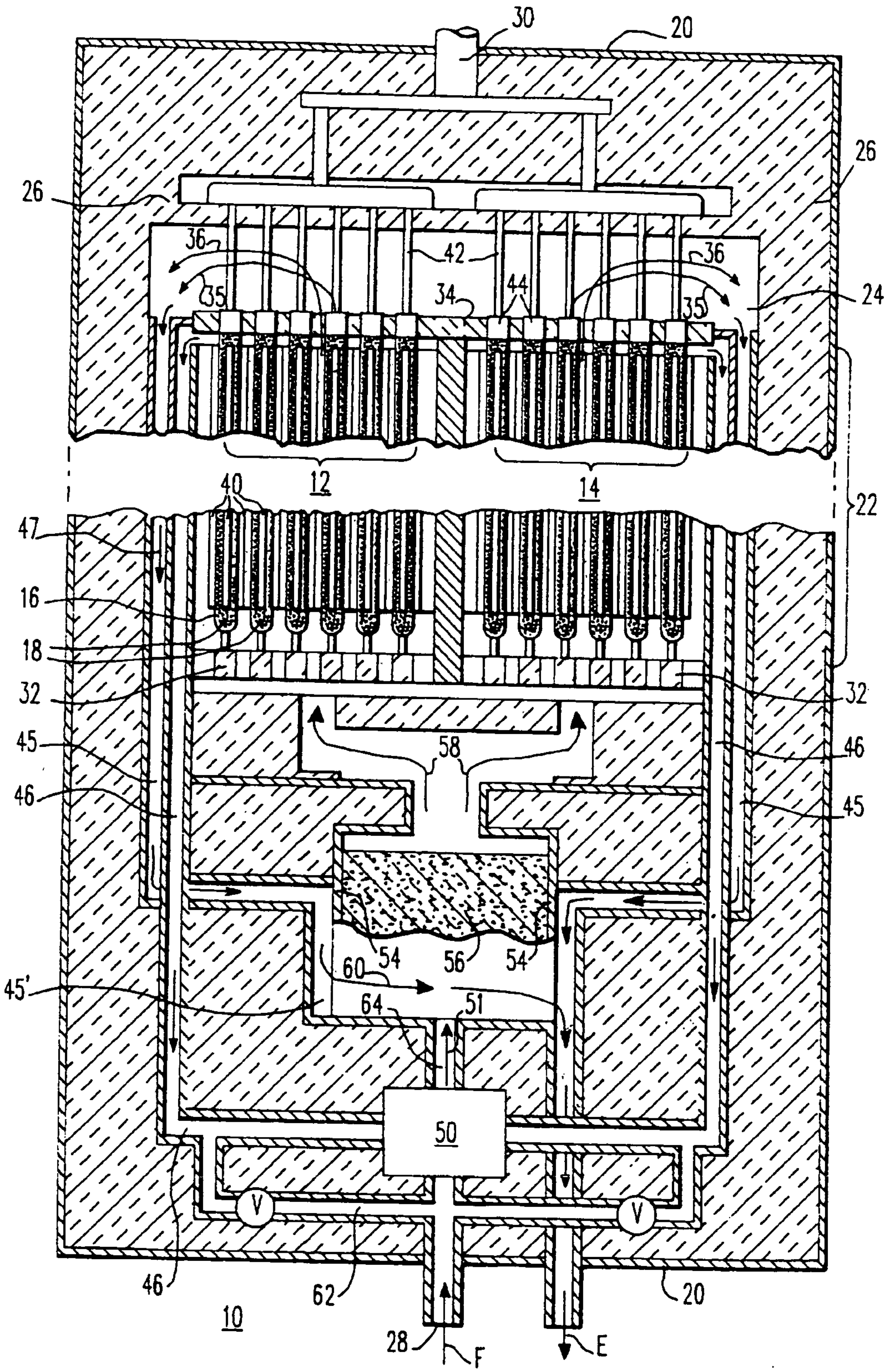
3. Appareil selon la revendication 1, caractérisé en ce que les cellules électrochimiques sont des piles à combustible, l'électrode à air contient du $LaMnO_3$ dopé, l'électrolyte est de la zircone stabilisée à l'oxyde d'yttrium et l'électrode à combustible contient un matériau cermet de zircone-nickel.

4. Appareil selon la revendication 1, caractérisé en ce que l'appareil de mélange et de mise en circulation est un mécanisme éjecteur.

5. Appareil selon la revendication 1, caractérisé en ce que le matériau de reformage catalytique est également réparti dans la chambre de générateur, sur ou à proximité des cellules ou ailleurs dans la chambre de générateur.

6. Appareil selon la revendication 1, caractérisé en ce que des ailettes de conduction thermique sont placées au niveau des points de contact du canal de sortie du gaz brûlé chaud et de la chambre de reformage.

7. Appareil selon la revendication 1, caractérisé en ce qu'il agit sur un oxydant gazeux et sur un combustible d'alimentation neuf gazeux.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